



# Time and Frequency-Domain Cross-Verification of SLS 6DOF Trajectory Simulations

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## ABSTRACT

The Space Launch System (SLS) Guidance, Navigation, and Control (GNC) team and its partners have developed several time- and frequency-based simulations for development and analysis of the proposed SLS launch vehicle. The simulations differ in fidelity and some have unique functionality that allows them to perform specific analyses. Some examples of the purposes of the various models are: trajectory simulation, multi-body separation, Monte Carlo, hardware in the loop, loads, and frequency domain stability analyses. While no two simulations are identical, many of the models are essentially six degree-of-freedom (6DOF) representations of the SLS plant dynamics, hardware implementation, and flight software. Thus at a high level all of those models should be in agreement.

Comparison of outputs from several SLS trajectory and stability analysis tools are ongoing as part of the program's current verification effort. The purpose of these comparisons is to highlight modeling and analysis differences, verify simulation data sources, identify inconsistencies and minor errors, and ultimately to verify output data as being a good representation of the vehicle and subsystem dynamics. This paper will show selected verification work in both the time and frequency domain from the current design analysis cycle of the SLS for several of the design and analysis simulations. In the time domain, the tools that will be compared are MAVERIC, CLVTOPS, SAVANT, STARS, ARTEMIS, and POST 2. For the frequency domain analysis, the tools to be compared are FRACTAL, SAVANT, and STARS. The paper will include discussion of these tools including their capabilities, configurations, and the uses to which they are put in the SLS program.

Determination of the criteria by which the simulations are compared (matching criteria) requires thoughtful consideration, and there are several pitfalls that may occur that can severely punish a simulation if not considered carefully. The paper will discuss these considerations and will present a framework for responding to these issues when they arise. For example, small event timing differences can lead to large differences in mass properties if the criteria are to measure those properties at the same time, or large differences in altitude if the criteria are to measure those properties when the simulation experiences a staging event. Similarly, a tiny difference in phase can lead to large gain margin differences for frequency-domain comparisons of gain margins.